TOPIC 14 Interference (Superposition)

1

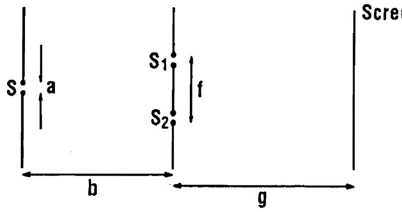


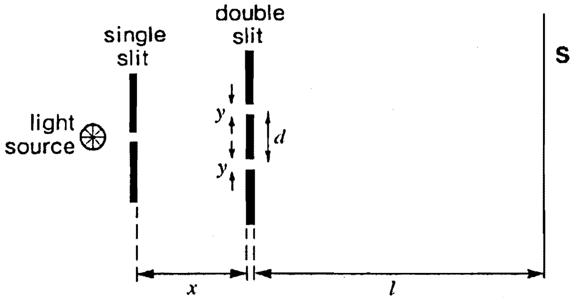
Fig. 1

Fig. 1 represents a Young's slits arrangement, in which a is the width of the primary slit S, b its distance from the secondary slits S_1S_2, f the separation of the secondary slits and Δx the separation of the bright bands on the screen. If λ is the wavelength of the monochromatic light used, then the separation Δx is

A $\lambda f/g$
B $\lambda g/f$
C $\lambda b/g$
D $\lambda b/a$
E $\lambda^2 a/bg$

N76/II/13

2 In the Young's slits arrangement shown, a pattern of equally-spaced, parallel fringes appears on a screen placed at S.



Which quantity, if increased, would cause the separation of the fringes to increase?

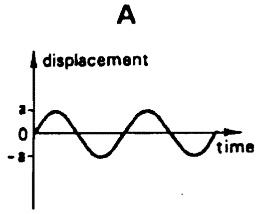
A x C d
B y D l

J77/II/12; J95/I/12

3 Wave generators S_1 and S_2 generate waves of equal wavelength. At a point **P**, S_1 by itself produces an oscillation of amplitude $2a$, and S_2 produces an oscillation of amplitude a, and there is a phase difference of π between the oscillations.

Which graph best represents the result oscillation at **P** when both generators are switched on?

A



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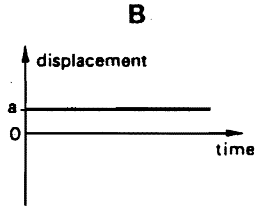

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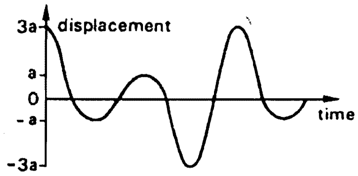

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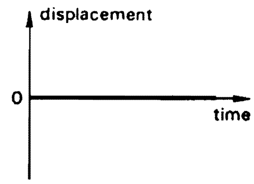
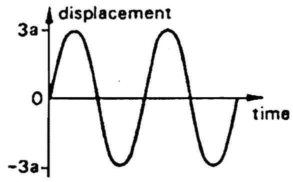


E



N77/II/9; J89/I/10

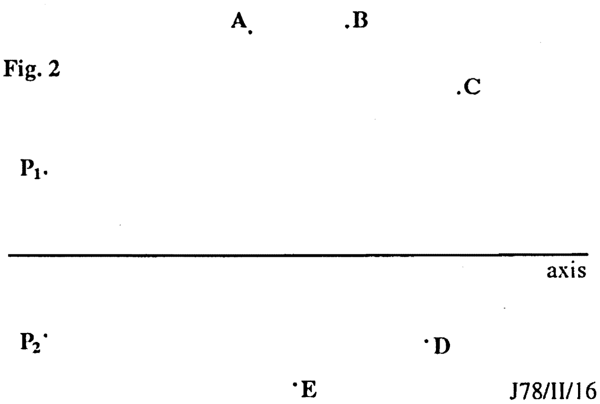
4 In a Young's double slit experiment, a small detector measures an intensity of illumination of I units at the centre of the fringe pattern. If one of the two (identical) slits is now covered, the measured intensity will be

A 2I B I C $\frac{I}{\sqrt{2}}$ D $\frac{I}{2}$ E $\frac{I}{4}$

N77/II/16

5 An interference experiment is set up using two identical, coherent sources of 1 cm waves. Fig. 2 shows, to scale, the positions of the sources P_1 and P_2 and of five observation stations, A to E. Which station will be at a position corresponding to the second off-axis maximum? (Use a ruler or a piece of graph paper as a scale for measuring distances.)

Fig. 2



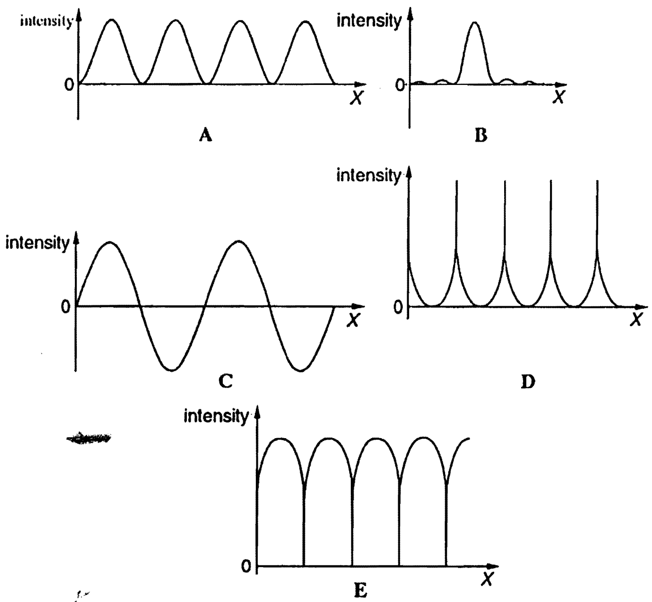
J78/II/16

6 Which one of the following statements must be true about two wave-trains of monochromatic light arriving at a point on a screen if the wave-trains are coherent?

A They are in phase.
B They have a constant phase difference.
C They have both travelled paths of equal length.
D They have approximately equal amplitudes.
E They interfere constructively.

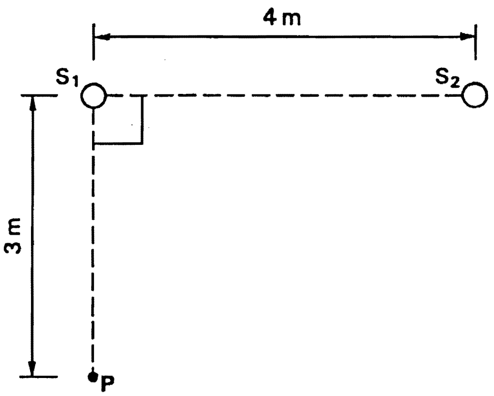
N78/II/11

7 Two coherent monochromatic waves of equal amplitude are brought together to form an interference pattern on a screen. Which one of the following graphs could represent the variation of intensity with position x across the pattern of fringes?



N79/II/11; J86/I/10

8 Two wave generators S_1 and S_2 produce water-waves of wavelength 2 m. They are placed 4 m apart in a water tank and a detector **P** is placed on the water surface 3 m from S_1 as shown in the diagram.



When operated alone, each generator produces a wave at **P** which has an amplitude A.

When the generators are operating together and in phase, what is the resultant amplitude at **P**?

- **A** 0
- **B** $\frac{1}{2}A$
- **C** A
- **D** $2A$
- **E** $4A$

J80/II/10; N88/I/8

9 Two identical narrow slits S_1 and S_2 are illuminated by light of wavelength λ from a point source P.

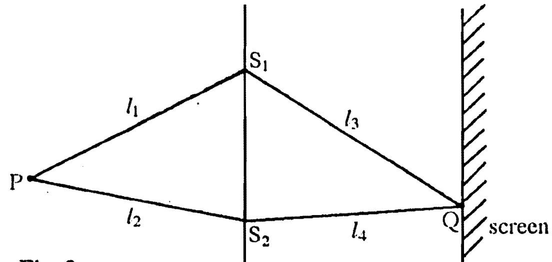


Fig. 3

If, as shown in the diagram above (Fig. 3), the light is then allowed to fall on a screen, and if m is a positive integer, the condition for destructive interference at Q is that

- **A** $(l_1 - l_2) = (2m + 1)\,\lambda/2$
- **B** $(l_3 - l_4) = (2m + 1)\,\lambda/2$
- **C** $(l_3 - l_4) = m\lambda$
- **D** $(l_1 + l_3) - (l_2 + l_4) = (2m + 1)\,\lambda/2$
- **E** $(l_1 + l_3) - (l_2 + l_4) = m\lambda$

N80/II/9

10 The diagram (Fig. 4) shows two similar loudspeakers driven in phase from a common audio-frequency source.

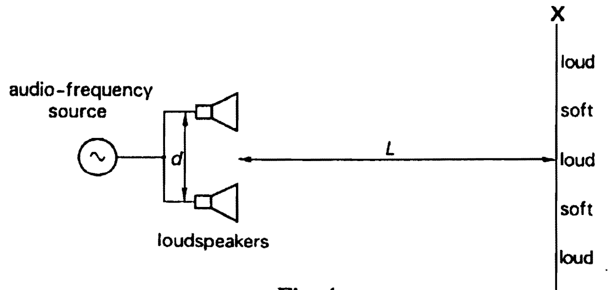


Fig. 4

When a student moves from **X** to **Y**, the intensity of the note he hears is alternately loud and soft.

The distance between adjacent loud and soft regions may be reduced by

- **A** decreasing distance d.
- **B** increasing distance L.
- **C** increasing the amplitude.
- **D** decreasing the amplitude.
- **E** using a higher frequency.

J81/II/12; N83/II/11; N86/I/12; N93/I/10

11 Coherent light is incident on two fine parallel slits, S_1 and S_2, as shown in the diagram below (Fig. 5)

Fig. 5

A dark fringe occurs at P when, n being an integer, the phase difference between the wavetrains from S_1 and S_2 is

- **A** $n\pi$ rad
- **B** $(n + \frac{1}{2})\,\pi$ rad
- **C** $2n\,\pi$ rad
- **D** $(2n + \frac{1}{2})\pi$ rad
- **E** $(2n + 1)\,\pi$ rad

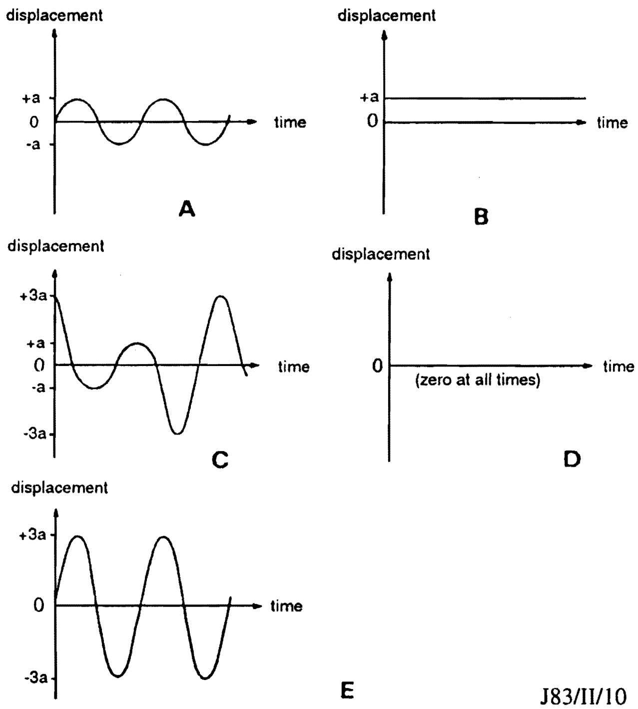
N81/II/15

12 Sound from a small loudspeaker L reaches a point P by two paths which differ in length by 1.2 m. When the frequency of the sound is gradually increased, the resultant intensity at P goes through a series of maxima and minima. A maximum occurs when the frequency is 1000 Hz and the next maximum occurs at 1200 Hz. What is the speed of sound in the medium between L and P?

A $200\ \text{m s}^{-1}$
B $240\ \text{m s}^{-1}$
C $480\ \text{m s}^{-1}$
D $1200\ \text{m s}^{-1}$
E $1440\ \text{m s}^{-1}$

J82/II/11

13 Water-wave generators S_1 and S_2 generate waves of equal frequency. There is no phase difference between the two generators. At a point P such that $(S_1P - S_2P)$ is equal to half a wavelength, S_1 by itself produces an oscillation of amplitude $2a$ and S_2 by itself produces an oscillation of amplitude a. When both generators are switched on, which one of the graphs below correctly describes the resultant oscillation at P?



J83/II/10

14 Coherent microwave sources S and S', placed a distance d apart as shown below (Fig. 6), emit waves of wavelength 30 mm.

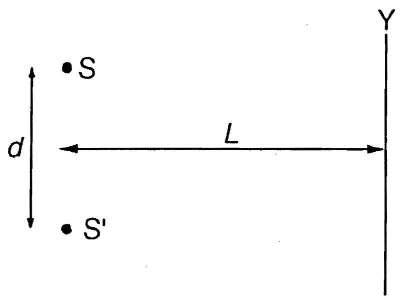


Fig. 6

What are suitable values for d and L if interference fringes are to be formed along YY'?

	d/mm	L/mm
A	1	1000
B	3	100
C	30	30
D	30	1000
E	300	1000

J83/II/11

15 The diagram below (Fig. 7) illustrates an experimental arrangement that produces interference fringes with a double slit.

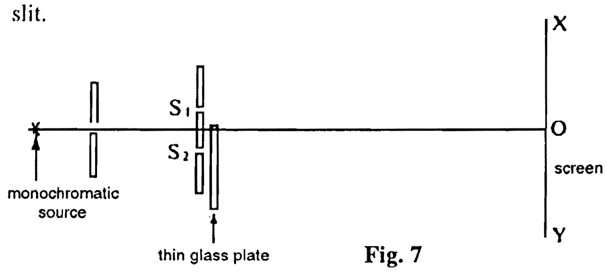


Fig. 7

When slit S_2 was covered with a very thin plate of glass as shown,

A the separation of the fringes increased.
B the separation of the fringes decreased.
C the fringe pattern moved towards X.
D the fringe pattern moved towards Y.
E the separation of the fringes decreased in the region OY but was unchanged in the region OX.

J84/II/13

16 When a two-slit arrangement was set up to produce interference fringes on a screen using a monochromatic source of green light, the fringes were found to be too close together for convenient observation. In which of the following ways would it be possible to increase the separation of the fringes?

A Decrease the distance between the screen and the slits.
B Increase the distance between the source and the slits.
C Have a larger distance between the two slits.
D Increase the width of each slit.
E Replace the light source with a monochromatic source of red light.

N87/I/10

17 Under which conditions will the bright fringes of a double-slit light interference pattern be farthest apart?

	distance between slits	*distance from slits to screen*	*wavelength of source*
A	small	small	short
B	small	large	short
C	small	large	long
D	large	small	short
E	large	small	long

J88/I/10; N92/I/11

18 Coherent monochromatic light illuminates two narrow parallel slits and the interference pattern that results is observed on a screen some distance beyond the slits.

Which modification increases the separation between the dark lines of the interference pattern?

A decreasing the distance between the screen and the slits
B increasing the distance between the slits
C using monochromatic light of higher frequency
D using monochromatic light of longer wavelength

N90/I/14; J99/I/12

19 Coherent light is incident on two fine parallel slits, S_1 and S_2, as shown in the diagram.

If a dark fringe occurs at **P**, which of the following gives possible phase differences for the light waves arriving at **P** from S_1 and S_2?

A $2\pi, 4\pi, 6\pi \ldots$
B $\pi, 3\pi, 5\pi \ldots$
C $\pi, 2\pi, 3\pi \ldots$
D $\frac{1}{2}\pi, \frac{5}{2}\pi, \frac{9}{2}\pi \ldots$
E $\frac{1}{2}\pi, \frac{3}{2}\pi, \frac{5}{2}\pi \ldots$

J93/I/10

20 Fringes of separation y are observed in a plane 1.00 m from a Young's slit arrangement illuminated by yellow light of wavelength 600 nm.

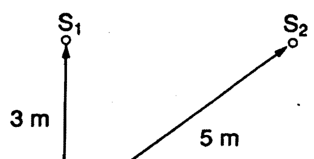
At what distance from the slits would fringes of the same separation y be observed when using blue light of wavelength 400 nm?

A 0.33 m
B 0.67 m
C 0.75 m
D 1.50 m

N95/I/12

21 Water waves of wavelength 4 m are produced by two generators, S_1 and S_2, as shown.

Each generator, when operated by itself, produces waves which have an amplitude A at **P**, which is 3 m from S_1 and 5 m from S_2.



When the generators are operated in phase, what is the amplitude of oscillation at **P**?

A 0
B $\frac{1}{2}A$
C A
D $2A$

J97/I/11

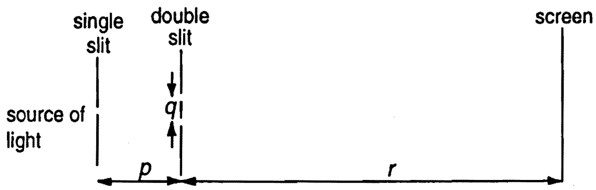
22 Light of wavelength 600 nm falls on a pair of slits, forming fringes 3.00 mm apart on a screen.

What would the fringe spacing become if the wavelength were 300 nm?

A 0.75 mm
B 1.50 mm
C 3.00 mm
D 6.00 mm

J98/I/12

23 A teacher sets up the apparatus shown to demonstrate a two-slit interference pattern on the screen.



The teacher wishes to increase the fringe spacing.

Which change to the apparatus will increase the fringe spacing?

A decreasing the distance p
B decreasing the distance q
C decreasing the distance r
D decreasing the wavelength of the light

N2000/I/11

***24** In a Young's double slit experiment, coherent monochromatic light of wavelength 4×10^{-7} m illuminates two narrow parallel slits separated by 10^{-3} m.

(a) What is the angular separation in radians of the resulting interference fringes?

If each slit were 10^{-5} m wide

(b) estimate the angle in radians between the axis of the system and the first minimum of the diffraction pattern produced by each of the slits.

J76/I/3

25 An essential condition for interference to be observable between wavetrains originating from two sources is that the sources should be coherent. Explain what is meant by *coherent* in this context.

J78/I/6; J83/I/5; J89/III/1

26 A student sets up the apparatus illustrated in Fig. 8 in order to observe two-source interference fringes.

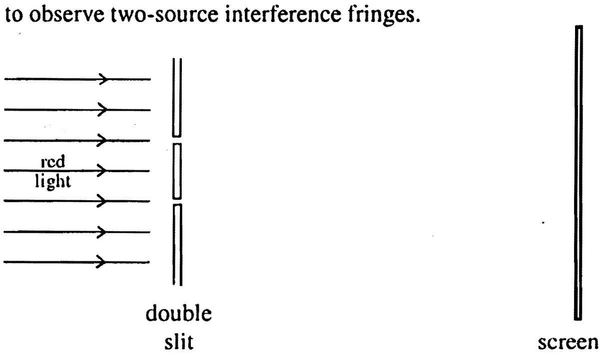


Fig. 8 (not to scale)

(a) State a suitable separation for the two slits in the double slit. [1]

(b) State and explain what change, if any, occurs in the separation of the fringes and in the contrast between bright and dark fringes observed on the screen, when each of the following changes is made separately.

(i) increasing the intensity of the red light incident on the double slit [3]

(ii) increasing the distance between the double slit and the screen [4]

(iii) reducing the intensity of light incident on one slit of the double slit [3]

N99/II/3

27 (c) Two microwave sources A and B are in phase with one another. They emit waves of equal amplitude and of wavelength 30.0 mm. They are placed 140 mm apart and at a distance of 810 mm from a line OP along which a detector is moved, as shown in Fig. 9.

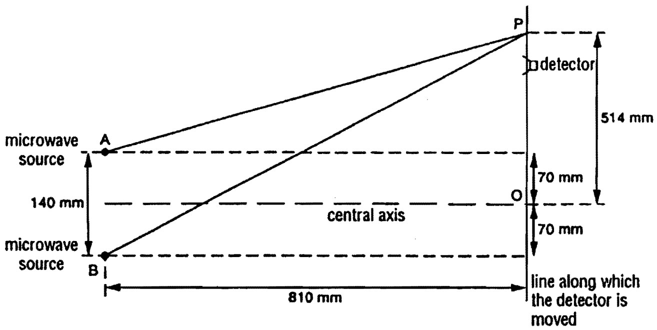


Fig. 9 (not to scale)

(i) Using Pythagoras' theorem, it can be shown that the distance AP is 923.7 mm. Calculate the number of wavelengths between source A and point P. [1]

(ii) Show that there are 33.3 wavelengths between source B and point P. [2]

(iii) 1. State what intensity of microwaves will be received by the detector when it is at P.

2. Describe how the intensity of reception varies as the detector is moved from P to the point O on the central axis. [3]

J2000/II/4 (part)

Long Questions

28 What do you understand by *diffraction* and *interference*?

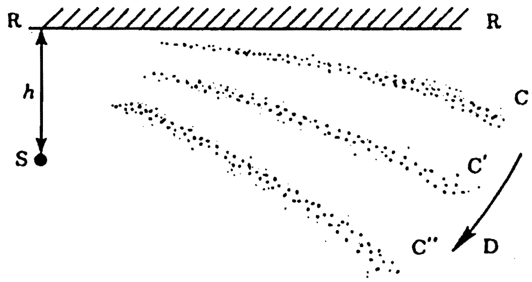
J77/III/2 (part)

29 It is possible to use two separate oscillators feeding two loudspeakers to demonstrate interference of sound. It is not possible to use two filament lamps, however similar, to produce interference of light. Explain this difference.

N78/III/2 (part)

30 Give the *theory* of an experiment to determine the wavelength of yellow light using two narrow slits. Point out any approximations you make.

Why is a third slit usually necessary?



A source S of continuous waves a distance h from a plane reflector R produces regions of high intensity such as C, C' and C''. Account for this. When the frequency of S is changed slowly, the regions C, C' and C'' move in the direction D as shown. Account for this, and deduce whether the frequency has been increased or decreased.

In Appleton's experiment, S was a radio transmitter on the Earth's surface, and R was the Heaviside layer – a reflecting layer in the atmosphere 80 km above the ground. When the wavelength transmitted slowly changed from 200 m to 180 m, a receiver on the ground 120 km away from S observed fluctuations in the received signal strength. Calculate the number of signal strength maxima observed during this change of frequency. J79/III/1

31 What do you understand by (a) coherence, (b) interference, between two separate wave trains?

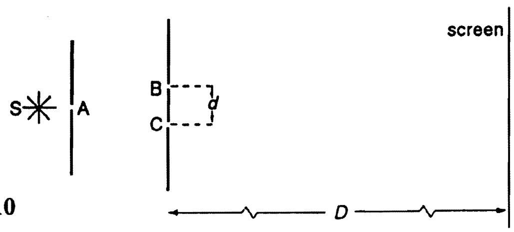


Fig. 10

Fig. 10 illustrates apparatus for an optical "Young's slits" experiment. A source of light S illuminates a narrow slit A which acts as a source for the narrow slits B and C and produces fringes on the screen. With light of wavelength λ, bright fringes are formed on the screen with a separations s. Derive a relation between λ, s, d and D. Suggest suitable values for d and D.

Describe and explain what happens to the fringes if

(i) both slits B and C are made narrower whilst keeping d constant,

(ii) the light emerging from slit B is reduced in intensity to half that from slit C,

(iii) a thin sheet of transparent plastic is inserted between slit B and the single slit A,

(iv) slits B and C are both covered with sheets of polaroid and that in front of B is slowly rotated. J85/III/8

32 State two conditions necessary for the superposition of two waves to give rise to a well-defined interference pattern.

J87/III/10 (part)

33 *(a)* (i) Sketch a graph to show the variation of intensity in the diffraction pattern formed when monochromatic light passes through a single narrow slit. [4]

(ii) Draw a labelled diagram to illustrate the apparatus you would use to demonstrate single-slit diffraction. Suggest suitable dimensions for the apparatus. [4]

(b) Fig. 11 illustrates apparatus which may be used for an optical double-slit interference experiment.

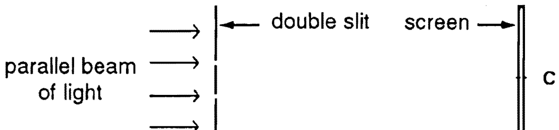


Fig. 11 (not to scale)

Fringes are observed on the screen, the central one being located at C. Describe and explain the appearance of the central fringe and its nearest neighbours when the light is

(i) monochromatic, (ii) white. [8]

(c) Fig. 12 shows the fringes produced when monochromatic light was passed through a double slit in which the width of each slit was about one quarter of their separation.

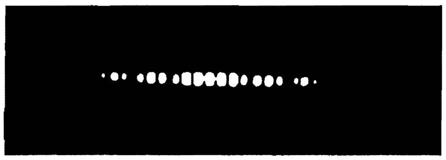


Fig. 12

Explain the parts played by diffraction and interference in the formation of these fringes. [6]

N89/III/8 (part)

34 *(a)* (ii) Explain how superposition contributes towards the effects observed when coherent monochromatic light passes through two very narrow parallel slits placed close together. [4]

(b) Parallel coherent light is incident upon two slits S_1 and S_2 and shown in Fig. 13.

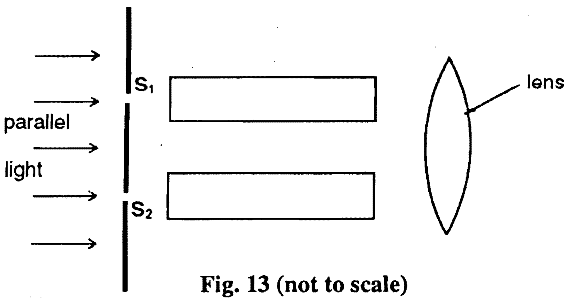


Fig. 13 (not to scale)

Light emerging from the slits passes through two identical evacuated tubes and is then superposed and viewed in the region around **E**.

(i) Describe what will be observed near **E** if

(1) S_2 is covered,

(2) S_1 and S_2 are both uncovered and the path lengths from S_1 to **E** and from S_2 to **E** are identical. [5]

(ii) When gas is allowed to leak gradually into the tube in front of S_2, the intensity of the light at the point **E** is found to change periodically. Explain how this observation leads to the conclusion that the speed of light in the gas is different from that in a vacuum. You may assume that the frequency of the light is constant. [4]

(iii) Light of wavelength 519 nm in a vacuum is observed to undergo 312 complete cycles in the variation of its intensity at **E** as the gas is introduced into the tube. The tube length is 62.0 cm. Obtain a numerical value for the ratio

$$\frac{\text{speed of light in vacuum}}{\text{speed of light in the gas}}$$ [5]

J90/III/6 (part)

35 *(d)* Describe an experiment which you could do with either sound waves or microwaves to demonstrate interference. Explain how you could use the experiment to find a value for the wavelength of the waves. [6]

(e) Why would an experiment using two separate sources of light not show interference? How could you modify the experiment in order to show interference of light? [4]

J91/III/2 (part)

36 *(b)* What conditions must be satisfied in order that two-source interference fringes may be observed? [5]

(c) A double slit with slit separation 0.800 mm is situated a distance 2.50 m from a thin jet of high speed smoke as shown in Fig. 14.

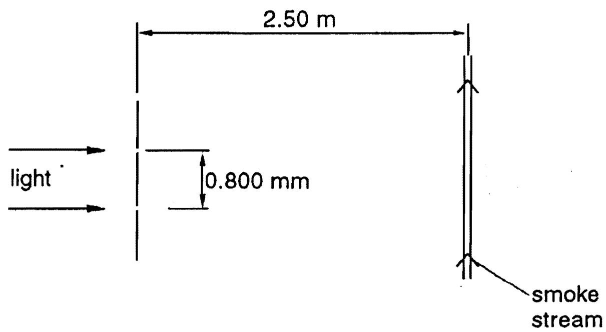


Fig. 14 (not to scale)

The double slit is illuminated with coherent light of wavelength 589 nm. Fringes are observed in the moving smoke. Calculate the separation of these fringes. [3]

(d) State with a reason the change, if any, that would be observed in the pattern of fringes if the following adjustments were made in the experimental arrangement. In each case, only the one adjustment is made and all the other arrangements are as initially in (c).

(i) The coherent light of wavelength 589 nm is replaced with coherent monochromatic red light.

(ii) The speed of the smoke stream is doubled.

(iii) The direction of the smoke stream is rotated through 45° as shown in Fig. 15.

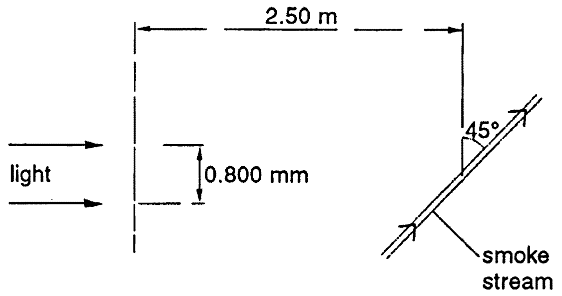


Fig. 15 (not to scale)

(iv) The smoke stream is replaced by a fixed screen. [8]

J92/III/2 (part)

37 (a) The wavelength of the monochromatic light from a lamp is to be determined by means of a double-slit interference experiment.

(i) Outline the experiment. State what measurements are taken and explain how these measurements are used to calculate the wavelength.

(ii) Give approximate values for the separation of the two slits and the width of one of these slits.

(iii) Explain briefly the parts played by diffraction and by interference in the production of the observed fringes. [10]

J94/III/5 (part)

Superposition

38 The energy carried by a wave-train is proportional to the square of the wave amplitude. If two waves of the same frequency are superposed in phase, the total energy carried is proportional to

A the sum of the energies carried by the separate waves.

B the mean value of the energies carried by the separate waves.

C the square of the mean value of the two amplitudes.

D the square of the difference of the two amplitudes.

E the square of the sum of the two amplitudes.

J81/II/9

39 The principle of superposition states that

A the total displacement due to several waves is the sum of the displacements due to those waves acting individually.

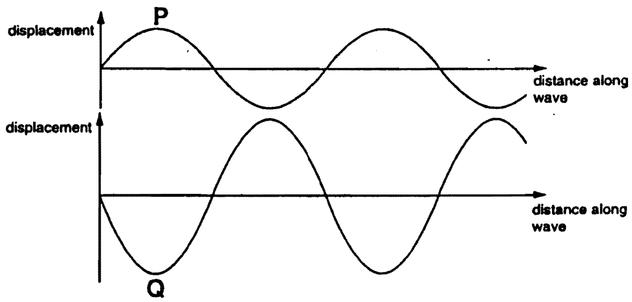
B two stationary waves superimpose to give two progressive waves.

C a diffraction pattern consists of many interference patterns superimposed on one another.

D two progressive waves superimpose to give a stationary wave.

E the frequency due to two waves is the difference between the frequencies of those waves. J86/I/9

40 The diagram shows the displacements at the same instant of two waves, **P** and **Q**, of equal frequency and having amplitudes Y and $2Y$, respectively.



The waves are superimposed to give a resultant wave.

What is the amplitude of the resultant wave and what is the phase difference between the resultant wave and wave **P**?

	amplitude of resultant wave	*(phase difference between resultant wave and wave **P**)/radians*
A	Y	0
B	Y	π
C	$3Y$	0
D	$3Y$	π

N96/I/12

41 Two coherent waves of intensities I and $2I$ meet in phase at a point. Given that intensity is proportional to $(\text{amplitude})^2$ for these waves, calculate, in terms of I, the intensity of the resultant wave at that point.

J87/III/2

42 A particle in a medium is oscillating because of the passage of a transverse wave T_1 of intensity I. Fig. 16 shows the variation with time t of the displacement of x of the particle. The amplitude of the oscillation is A.

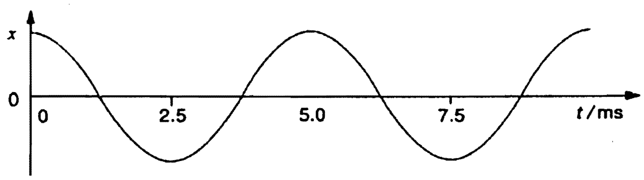


Fig. 16

A second, similar transverse wave T_2 has the same frequency but the amplitude of the oscillation due to T_2 alone is $3A/2$.

(a) Calculate

(i) the frequency of the waves,

(ii) the intensity, in terms of I, of the wave T_2. [3]

(b) State two conditions which are necessary for the waves T_1 and T_2 to interfere. [2]

(c) (i) What additional condition must be satisfied when the waves interfere if the resultant intensity is to be a minimum?

(ii) Calculate, in terms of I, this minimum intensity. [4]

J95/II/2

43 *(a)* Two waves of different frequency pass through the same point. Figs. 17 and 18 show the displacement-time graphs for the waves. On Fig. 19, sketch the resultant displacement showing the superposition of these two waves. [2]

Fig. 17

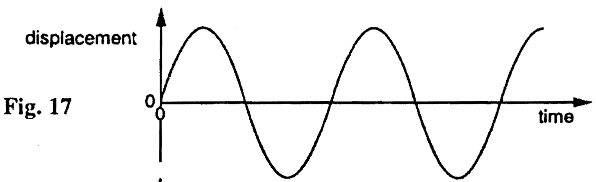


Fig. 18

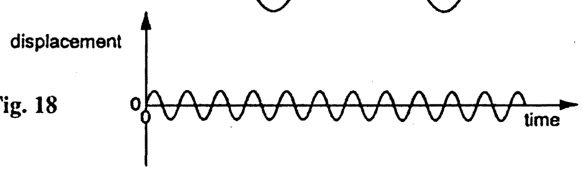
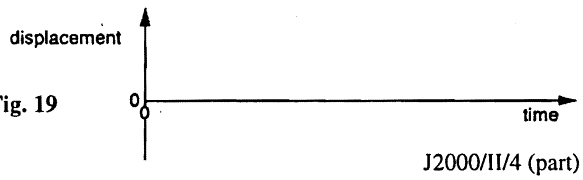


Fig. 19



J2000/II/4 (part)

Long Questions

44 *(a)* (i) What do you understand by *superposition*? [2]

J90/III/6 (part)

45 *(a)* What is meant by the term *superposition* when applied to waves? Describe briefly a demonstration which you could do in a laboratory to illustrate superposition. [4]

N94/III/2 (part)